PROGRESS REPORT ON SUPPRESSION AND DETECTION RESEARCH IN THE U.S.

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ABSTRACT

Progress in the area of fire suppression and detection has been dominated by the search for environmentally friendly replacements for Halons 1211 and 1301 and the investigation of new technologies borrowed from other fields for application in fire detection. New methods of characterizing the suppression of furnishing fires have lead to means of incorporating the fire suppression effects of sprinklers into predictive fire models. A limited water supply sprinkler system has been developed for installation in mobile homes. The minimum flow requirement for the system is 0.82 ℓ/s from a reservoir with a minimum capacity of 378 liters.

1. PROGRESS IN SUPPRESSION: HALON ALTERNATIVES

The current commercial halons have been identified as contributing to the depletion of the earth's stratospheric ozone. As a result, their manufacture has been limited to 1986 levels by the Montreal protocol, and more severe limitations are anticipated in the near-future. As a necessary step in the search for alternatives, a government/industry program was established to identify and qualify candidate replacements for halons 1301 and 1211 that will satisfy the needs of the major users for existing applications. No such search has been conducted since the late 1940s, when the U.S. Army conducted the study that led to today's predominant halogenated fire suppressants: halons 1301 (CF_3Br) and 1211 (CF_2ClBr).

Replacements for the current halons must have a number of critical properties: fire suppression efficiency, low residue level, low electrical conductivity, low metals corrosion, high materials compatibility, stability under long-term storage, low toxicity (inhalation and contact) of the chemical and its combustion products, and low (or zero) contributions to stratospheric ozone depletion and global warming. These constraints are expected to complicate the search.

The search strategy selected by the National Institute of Standards and Technology (NIST) team focusses on principles for efficient fire suppression and low contribution to stratospheric ozone depletion. The widest range of chemical families were researched for their potential to test these principles. Some of these families have not previously been considered for fire suppression.

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There are nine families of chemicals with potential for workbench testing of the above principles.

- Saturated halocarbons or halons: ($C_nF_oCl_pBr_qI_r$ where $o+p+q+r=2n+2$). These are analogs of the currently-used halons and include totally fluorinated compounds, photosensitive compounds, and analogs to the HCFCs.

- Halogenated ketones, anhydrides, and esters. These contain C=O bonding and may be more prone to solar dissociation in the troposphere.

- Unsaturated halocarbons. These contain C=C bonding and may be more reactive with OH in the troposphere.

- Halogenated ethers. These contain an O-C-O linkage, which is thought to promote solar dissociation in the troposphere.

- Halons containing iodine. These are likely to be more reactive in the troposphere.

- Sulfur halides. These are analogs to the halons.

- Compounds containing phosphorus. These are non-ozone-depleting, possibly highly efficient fire suppressants.

- Silicon and germanium compounds. These are tropospherically-reactive analogs to the halons.

- Metallic compounds. These are extremely efficient fire inhibitors that are non-ozone-depleting.

- Inert gases. These are baseline chemicals: less-efficient, only physically active agents with zero ozone-depletion potential.

A list of 103 chemicals which were selected from these families has been published as being beneficial for further study as possible candidate alternatives or as compounds that may aid in defining the principles of fire suppression [1].

A systematic and effective means has been found to evaluate the candidates through a program of closely-coordinated research, empirical testing, and analysis. The following factors were identified as important in specifying the testing procedures:

- ease of operation for these types of chemicals,
- number of locations having the capability to perform the test,
- amount of chemical required, and
- relevance of the figure(s) of merit to this program.

It was necessary in several cases to make adaptations to existing methods or in some cases develop new methods and procedures from the most appropriate current practice.

Nine screening procedures have been defined for characterizing potential candidates for replacing halons, particularly 1211 and 1301, now in use for fire suppression applications. These screening procedures have shown that they are able to distinguish between gases and liquids of varying degrees of performance [2].

At present, there is no clear winner(s) among the candidate materials for replacing halon 1211 or 1301.

2. PROGRESS IN SUPPRESSION: SPRINKLERS

2.1 Sprinkler Fire Suppression Algorithm

For many years sprinkler actuation prediction models have been part of the technology available to determine when automatic fire suppression would begin, but there were no models to continue the process by predicting the effect of the sprinkler water spray on the fire. As part of studies conducted for the U.S General Services Administration, an algorithm for prediction of the maximum post-sprinkler actuation heat release rate (HRR) from office furnishings fires was developed [3] based on large scale experiments.

The sprinkler fire suppression algorithm consists of multiplying the HRR reduction factor by the HRR at the time of sprinkler activation, $\dot{Q}_{act}$, yielding an expected upper bound to the HRR at a given time after sprinkler activation, $\dot{Q}(t)$, for office furnishing fires that are not heavily shielded.

$$\dot{Q}(t) = \dot{Q}_{act}\, e^{-0.0023t}$$

This sprinkler fire suppression algorithm can be thought of as a "zeroth order" fire suppression model for "light hazard" occupancies with a sprinkler spray density of 0.07 mm/s (0.1 gpm/ft^2) or greater.

2.2 Limited-Water-Supply Sprinkler System for Mobile Homes

The current standard for the installation of sprinkler systems into single family homes, requires a minimum water flow rate of 0.0016 m^3/s (26 gpm) for 600 s. The size and cost of these systems are impractical for some dwellings such as mobile homes.

Under a research and development program sponsored by the United States Fire Administration, Factory Mutual Research Corporation [4] and Underwriters Laboratories [5] a Limited-Water-Supply (LWS) sprinkler system has been developed. Through the use of reduced sprinkler spacing from 3.66 m (12 ft) to 2.44 m (8 ft) and quick response sprinkler technology the heat release rate of the test fires at first sprinkler actuation is reduced by 50% as compared with the existing standard single family home systems. The LWS sprinkler system uses less water and is primarily designed as a life safety system, i.e. prevent flashover and maintain tenable conditions for at least 7 minutes to allow time for occupants of the dwelling to escape. LWS design requires 0.38 m^3 (100 gal) of water with a minimum flow rate of 0.82 ℓ/s (13 gpm). FMRC has developed a LWS sprinkler [3] with a K factor of 28 ℓpm/(bar)$^{1/2}$ (2.0 gpm/(psi)$^{1/2}$) and a volume mean drop size between 0.6 and 0.8 mm. Low cost installation technology is also being investigated to minimize the cost of the system.

3. PROGRESS IN DETECTION

Recent progress in fire detection was recorded in the review paper by Bukowski and Jason [6]. This work is based on an extensive review of the international literature published since 1975.

Advances in fire detection may come from transfer or integration of advanced technology used outside of the fire field. As examples, novel sensors for measuring smoke, chemicals, electromagnetic radiation and acoustic emission were discussed by Grosshandler and Jackson [7]. Grosshandler [8] looked at the latest technologies and attempted to identify their possible applications and limitations. Several promising areas in need of future research, including discriminating smoke/CO combination detectors, remote detection of fire using open-path FTIR, wide-band optical and audio detection systems, and laser/fiber-optic combination temperature/gas/particle detector systems. The most exciting new system is one based on intelligence borrowed from machine vision [9], in which the changes in intensity of the red, green and blue signals for each pixel in a CCD camera are followed in space and time. The system has been trained to determine a fire from a non-fire within an airplane hangar, and can make a decision in about 1/10 second with a very high level of confidence [10].

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5. REFERENCES

1. Pitts, W.M., Nyden, M.R., Gann, R.G., Mallard, W.G., and Tsang, W., "Construction of an Exploratory List of Chemicals to Initiate the Search for Halon Alternatives," NIST Tech Note 1279, National Institute of Standards and Technology, 1990.

2. Gann, R.G., Barnes, J.D., Davis, S., Harris, J.S., Harris, R.H., Herron, J.T., Levin, B.C., Mopsik, F.I., Notarianni, K.A., Nyden, M.R., Paabo, M., and Ricker, R.E., "Preliminary Screening Procedures and Criteria for Replacements for Halons 1211 and 1301," NIST Tech Note 1278, National Institute of Standards and Technology, 1990.

3. Madrzykowski, D. and Vettori, R.L., A Sprinkler Fire Suppression Algorithm for the GSA Engineering Fire Assessment System. Nat. Inst. Stand. Tech. (U.S.) NISTIR 4833; May 1992.

4. Bill, R.G., Kung, H.C., Hill, E.E., Chan, T.S., Brown, W.R., The Development of a Limited-Water-Supply Sprinkler for Mobile Homes. Factory Mutual Research Corp., Norwood, MA, FMRC J.I.0T1N7.RA; April 1992.

5. Final Report of Sprinkler Research Under Contract EMW-89-R-3083 for the Period October 1, 1989 -September 30, 1990. Underwriters Laboratories Inc., Northbrook, IL, 89NK25259/-NC188; December 1990.

6. Bukowski, R.W., and N.H. Jason (1991), "International Fire Detection Bibliography 1975-1990," NISTIR 4661, National Institute of Standards and Technology, September.

7. Grosshandler, W.L., and M. Jackson (1992), "Acoustic Emission of Structural Materials Exposed to Open Flames," Abstracts: Annual Conference on Fire Research, S.M. Smith, ed., p. 27, NISTIR 4924, National Institute of Standards and Technology, October.

8. Grosshandler, W.L. (1992), "An Assessment of Technologies for Advanced Fire Detection," Symposium on Heat Transfer in Fire and Combustion Systems, American Society of Mechanical Engineering, Winter Annual Meeting, November.

9. Goedeke, A.D., B. Duda, G. Healey, S. Viglione, and H.D. Gross (1990), "Machine Vision Fire Detector System (MVDS)," Report No. ESL-TR-91-02, Donmar Limited, Newport Beach, CA, Phase I SBIR Final Report, Air Force contract no. FO8635-C-90-0394, December 22.

10. Schwartz, D.B. (1992), "Machine Vision Fire Detection", Abstracts: Annual Conference on Fire Research, S.M. Smith, ed., p. 29, NISTIR 4924, National Institute of Standards and Technology, October.